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# GEOLOGICAL RECONNAISSANCE OF THE ISLAND OF LEYTE—WITH NOTES AND OBSERVATIONS ON THE ADJACENT SMALLER ISLANDS AND SOUTHWESTERN SAMAR.

By GEORGE I. ADAMS.
(*From the Division of Mines, Bureau of Science.*)

Little has been published concerning the geology of the Islands discussed in this report. Jagor, who visited the northeastern part of Leyte in 1860, noted the occurrence of a schist south of Tanauan, and described Bito Lake near Abuyog and the solfataras south of Burauen. His petrographic specimens were examined by Roth. A single specimen of igneous rock from the Island of Limasaua was described by Oebbeke who studied Semper's collections. Abella visited and described the Island of Biliran in 1882, especially its sulphur deposits. Becker cites passages from a manuscript report made by Ashburner in 1883 on the gold mines of the Island of Panaon. All the publications above mentioned were made use of by Becker in his report on the geology of the Philippines. In treating of the tectonic features of the islands, he discusses the structural relations of the Island of Leyte as surmised by others and adds some observations from his study of the maps. In the Atlas de Filipinas, prepared at the Jesuit Observatory in Manila, the conventional sign for an extinct volcano is shown on a general map of the islands near the name "Mount Amandiuing." This symbol, as will be explained later, may have been intended to indicate the solfataras south of Burauen. There is also a manuscript report by Maurice Goodman, formerly mining engineer of this division of the Bureau, which describes the sulphur deposits on Biliran Island and those near Burauen on Leyte visited by him in 1906.

No previous attempt has been made to describe the physiographic and geologic districts of Leyte and so the present report, although meager, may serve as an introduction. The reconnaissance on which it is based was made during April and the first half of May, 1909, while studying the geologic conditions governing the drilling of deep and artesian wells for the Bureau of Public Works. The island was circumnavigated and fifteen coast towns and three interior towns in the northeastern part were visited.

*Maps.*—The best map of Leyte is by d'Almonte, published on a scale of 1–200,000. It was evidently used in preparing the one published in the Atlas de Filipinas. On it the adjacent Islands of Biliran and Panaon are shown in some detail. The two most notable errors which it contains are in the representations of Lake Bito and the Leyte River. Jagor, who visited Lake Bito, has shown that it was drawn too large on Coello's map, which may have been d'Almonte's source of information. The description of the lake, translated from the Spanish edition of Jagor's travels, is as follows:

> "The rain having passed, we arrived at the Bito River in an hour (from Abuyog) by an agreeable road and in a banca ascended the river which follows through heavy vegetation. The margins are low, level and sandy, and are covered with tall bamboo and reeds. After having ascended ten minutes the way was found obstructed by fallen tree trunks, which obliged us to make a detour of half an hour on land in order to reach the river above the obstruction. Rafts of bamboo were constructed, on which we journeyed, very much crowded because of their small size, due to the little amount of material available. We arrived at the lake in ten minutes. To the north and south of the lake there are hills. Seen from the center, the lake is nearly circular and is surrounded by a forest. Coello represents it too large (4 sea miles instead of the one which it has). It is about 1 league distant from Abuyog. * * * We found the greatest breadth to be 585 brazas, equal to 977 meters (its greatest breadth must be a little more than 1 kilometer) and its length is about 1,007 brazas, equal to 1,680 meters, or less than a mile. Soundings showed the bottom to incline gradually toward the center where the depth is 8 brazas, equal to 13.3 meters."

Lake Bito will be correctly shown on a Coast and Geodetic Survey chart now in preparation for publication.

There is a general impression among those who have an opinion in regard to this lake, that it occupies a crater and that the hills which surround it are the remnants of a crater rim, but there is no information confirming this. The idea is suggested by the position and appearance of the hills in the plain, as seen from a steamer when leaving Abuyog for Dulag. The depth of the lake indicates a depression greater than would be expected from the grade of the stream. The locality is worthy of geologic investigation.

The Leyte River is much shorter than is indicated on published maps, and does not have its source in Lake Danao, nor is Danao the source of the Cancatoco River, as is shown on some maps. The Iwaásan River is the outlet of the lake, and it flows to the east to Amandiuing Lake which, in turn, is the source of the Binahaán. Lieut. Philip H. Rockstroh, of the Philippines Constabulary, kindly furnished this criticism, together with other information concerning the hot and mineralized springs and topographic features of the island, and his description of Lake Bito corresponds with the one by Jagor given above. On a manuscript atlas of the Philippines by d'Almonte, which is now the property of the Coast and Geodetic Survey, these features of the drainage near Lake Danaó are shown as here described. The errors in the published map may be due to the lithographer.

There are a number of sectional and route maps made by officers of the United States Army and Philippines Constabulary, but it is not possible at present to compile a satisfactory map. The Coast and Geodetic surveys now in progress, as well as surveys by the Bureau of Lands, indicate that many details of the Spanish maps will be changed when the present surveys are concluded and combined. Accordingly, in this report only an outline map on a small scale is used, and the reader who may have a special interest in the island is advised for the present to consult d'Almonte's map or the one in the Atlas de Filipinas, which was taken from d'Almonte's, and also the Coast and Geodetic Survey charts.

*Physiographic and geologic districts.*—No previous attempt has been made to describe the physiography of Leyte and the only suggestion as to its topographic features is in the disposition of the streams and the names of the mountains on the maps. The hachuring of d'Almonte's is, to say the least, misleading, and in the absence of elevations accompanying the names of the mountains, an imperfect idea of the relief is presented. The physiographic districts distinguished in this report correspond closely with the geologic structure and are accordingly indicated by the geologic districts on the accompanying outline map. The dominant feature of Leyte is the Central Cordillera which runs from Cabalian in a northwesterly direction through the island and is continued in Biliran and Maripipi Islands. In addition may be distinguished the southwestern semi-mountainous district, the northeastern semi-mountainous district and the northeastern plains. There are also some littoral lowlands of small extent which are not shown on the map.

## CENTRAL CORDILLERA.

This district is for the most part rugged and is dominated by many high peaks. Its lowest portion is to the west of Carigara, where it is also narrowest. This is the most practicable place for a road to cross the district, and a trail now exists which can be developed into a road.

The trail over the cordillera between Dolores to Jaro is very difficult, because of the steepness of the western slope, and it is impracticable for a wagon trail. There is an idea prevalent that a road should be established between Abuyog and Baybay following the river valley in so far as possible. This route has been surveyed by the division of roads, and some money has been spent in clearing a trail, but the route is not an easy one and the building and maintaining of a road in this section would be very costly.

Similarly, from Abuyog to Sogod the foot trail is rugged and difficult, and the coast between Abuyog and Hinunangan affords no place for the construction of a road. With the exception of the route from Carigara westward, it is probable that the Cordillera forms a barrier to transportation which will prove effective for a very long time.

*Mount Amandiuing.*—The only peak of the Central Cordillera which appears to be indicated in the Philippine Atlas as an extinct volcano is Amandiuing. No explanation of the reason for this is given and it may be that the symbol was intended to show the solfataras of Burauen. However, several military officers who have ascended the flanks of Amandiuing have stated that it has the appearance of an extinct volcano, and it may prove to be one since there is a hot sulphur mud spot on its flank, and there are hot springs at the source of a stream which heads in this peak and flows towards Jaro.

*Solfataras near Burauen.*—The solfatara of Casiboy south of Burauen is indicated on d'Almonte's map as situated in Mount Himalacagan. As will be seen from the succeeding quotations there is a second solftara near by.

The following description of these solfataras by Jagor is translated from the Spanish edition of his travels in the Philippines:

> "South of Burauen rises the mountain ridge Manacagan,[1] on the further slope of which is a large solfatara from which sulphur is obtained for the powder factory established in Manila. From the gateway there is seen to the south, through the shade of the trees, a great white slope of Mount Danan."
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> "At 9 o'clock we reached the crater of Casiboi where there is much vegetation and advancing to the south we saw some sheds in which sulphur is sublimated. A few hundred paces more to the south a stream flows 12 feet wide, the water of which is hot (30° Réaumur) and deposits siliceous sinter at its borders."
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> "Following from north to south along a ravine the walls of which have a height of from 100 to 200 feet, the vegetation gradually diminishes and the rock is so white as to affect the eyes. In places it is of a yellow color due to the sublimated sulphur deposited on it. In many places there rises from the ground a penetrating, dense vapor with a pronounced odor of sulphur. Several hundred paces beyond, the valley turns to the left (east) and widens. Here numerous siliceous springs break through the clayey earth which is impregnated with sulphur. This solfatara must formerly have been more active. The depression formed by the decomposition of the rock has a floor covered with débris and measures about 1,000 feet wide and five times as long."
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> "In the eastern part there are a number of small boiling mud spots. From holes made in their borders with a stick, water and steam ascend. In some

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[1] Mount Himalacagan on Abella's map.

deep places to the west beds of gray, white, red, and yellow clay lie deposited in layers and having the aspect of variegated marls."

"Exactly to the south in front of the gate-way on the trail from Burauen there is a cavern in white decomposed rock, having an opening 25 feet wide from which much water which deposits siliceous incrustations flows. The roof of the cave is hung with stalactites which are covered partially or completely with sublimed sulphur."

"In the high part of the slope of Mount Danán near the summit so much sulphur is deposited from the vapors that it can be collected in coconut shells. In some crevices protected from the action of the cold air it accumulates in thick brown crusts."

"The solfatara of Mount Danán is situated exactly south of the other at the opposite side of the ridge of the Casiboi. The clay, which remains after the siliceous matter has been washed out, is carried by the rain to the valley where it forms a plain, the greater part of which is occupied by the Lake Malaksan. (Malaksan signifies sour.) It is limited by low ground, and its extent, which is subject to frequent variations according to the weather, was found to be 500 paces long and 100 wide. From the elevation at the solfatara there is seen through an opening to the south a somewhat larger lake of fresh water surrounded by wooded mountains. Its name is Jarnanan. * * * Soundings gave the following results: Near the southern margin, which is somewhat more steep than the north, 13 fathoms (equals 21.7 meters); the greatest length was found to be 800 varas (668 meters) and the width about half of this."

Mr. Goodman described the same locality as follows; he introduced some names not contained in Jagor's description, but the reader will be able to reconcile the two descriptions without difficulty:

"The earliest indication of our proximity to solfataric activity was observed when we came to the crossing of the Mainit River, about a third of a mile south of 'la puerta.' The source of the heat and sulphur carried by the Mainit lies in the solfatara, which is only about a quarter of a mile east of where we crossed the river and about 100 feet above it. The To-od Grande, as this solfatara is called, is a large barren space about 800 feet long by 500 feet wide. Its surface consists of white kaolin resulting from the corrosion by acid fumes of some volcanic rock, probably andesite. A portion of this superficial layer has incrusted upon it a greenish yellow mixture of sulphur and clay, deposited from the sulphurous gases which still emanate from numerous fissures and crater-like openings in the surface of this barren area."

"These openings are of two kinds—dry vents from which gases escape into the atmosphere without the association of water, and wet holes which are like large earthern caldrons containing either boiling mud or water. Extending some distance around the orifice of the dry vents there is usually formed an incrustation of beautiful yellow crystals of sulphur. The bulk of the sulphur, however, lies in the impure clayey mixture distributed over the surface in irregular patches. An average sample of the crust to a depth of about nine inches yielded on analysis 66.1 per cent of free sulphur."

"The To-od Pequeño is a continuation of the same solfatara, situated to the south of and at a lower level than the To-od Grande. It exhibits the same phenomena as the upper solfatara, but is much smaller in area. In one portion of the To-od Pequeño is a large cave from the bottom of which issue steam, sulphurous, chlorine, and other gases, corroding the sides and roof of the vault and giving to it a vari-colored appearance, due to the secondary minerals formed."

"About half a mile southeast of the To-od and separated from it by a high ridge of andesite is another solfatara called the Pangujaan.[2] It is situated on the southern slope of a slide, about 125 feet high and about 300 feet wide, from the sides of which four or five larger and several smaller vents give off steam and sulphurous gases in a continuous flow. As at the To-od, these vents are usually fringed with a sublimate of sulphur, close approach to which, however, is very difficult on account of the precipitousness of the slide, as well as on account of the heat and noxious gases given off. Occasionally the channel leading to one of these vents may become closed, and the flow of gases deflected in another direction, in which event the rich sublimate which has formed in the neck and about the mouth of the vent becomes covered over with a subsequent layer of kaolin, forming a hidden deposit of almost pure sulphur."

"South and southwest of the two solfataras are two small lakes which drain that region. The smaller of these, called the Malaksan, has low and flat banks, is quite shallow, and is about 100 feet long by about 500 feet wide. Its waters are slightly acid, and apparently barren of all living matter. The larger and deeper of the two lakes, called the Pangi, is situated about half a mile south of lake Malaksan, has high, steep and wooded banks, and contains fresh water with an abundance of large fish. The approximate altitudes of the two lakes are respectively 1,230 and 1,160 feet above sea level. With the exception of a few occasional fishermen who venture into this country, the entire neighborhood of the solfataras is uninhabited and uncultivated for miles around."

*Mount Cabalian.*—Another topographical feature worthy of description is Mount Cabalian, which is situated in the extreme southeastern point of the island. Its lower slopes have the characteristics of a volcanic cone, but its summit is broken up into irregular peaks inclosing a lake which evidently occupies the crater. To the south and east the lower slopes of the mountain descend gradually to the sea, and to the northeast they descend with the same regularity to a lowland. To the north and west there are hills which destroy the outline of the cone. To the west and east of the mountain there are hot springs, and several of the streams which flow down its lower slope are slightly mineralized, so that fish do not live in them.

In Bulletin III, Census of the Philippines, 1905, Rev. Sáderra Masó, S. J., records that it is stated that near Cabalian there lies an active solfatara. This probably refers to Mount Cabalian which, however, does not exhibit solfataric action. In 1907 it was the center of a local earthquake disturbance which continued from May 17 to 25 and caused several large landslides from the peaks of the mountains. The barren rock faces and the paths of the descending avalanches, as indicated by the absence of trees, were clearly distinguishable at the time this reconnaissance was made. In the Bulletin of the Weather Bureau for May, 1907, the reports of this earthquake from inhabitants of the locality state that the disturbance caused some nipa houses to fall, and that on

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[2] Solfatara of Mount Danán of Jagor's description.

May 20 the shocks were so frequent that the people had difficulty in cooking their meals. In his report for May, 1907, Director Algué, of the Weather Bureau, writes concerning the character of the disturbance:

> "It is certain that these earthquakes, besides having a very reduced meizoseismic area (about 10 kilometers in diameter) must have proceeded from a center at a small depth, since of more than sixty disturbances felt in the epicentrum between the 17th and 25th of May, only eight were perceptible in Maasin, 30 kilometers distant, and four in the extreme northeast of Mindanao, which is 60 kilometers distant."

*Solfataras on Biliran Island.*—According to Abella the central cordillera continues to the north in the islands of Bilirán and Maripipi. He describes the Cordillera of Bilirán as extending from the northwest to southeast and lying near the eastern sides of the island, and then curving to the south where it terminates in abrupt slopes at the narrow strait which separates the island from Leyte.

The active solfataras of Bilirán are described by Abella as follows (translation from the original in Spanish):

> "The most important of all, the one in the drainage of the Caraycaray River, is situated in the place called Cajúco on the western slope of Mount Guinon on one of the spurs which gives rise to the Cailjián ravine. One sees at that place an elliptical space about 100 meters long entirely devoid of vegetation in which the rocks are whitened or of variegated colors produced by the deposits and concretions of various natures which are found there, and from some distance there is a noticeable sulphurous odor from the fumaroles at various points"

The mine San Antonio was located on this deposit.

> "The solfataras of the Caibiran River occur principally in three bare spots analogous to the one at Cajúcao situated parallel to the Mapulá ravine on the eastern side of Mount Guinón opposite those of Cajúcao. * * * These three spots or bare places present phenomena and products similar to the others just described. * * * However, the disintegrating products of the rocks are here more extensive, which seems to indicate that these sulphur deposits are somewhat older than that of the other slope and are in their period of decline or extinction."

The mine Santa Rosalia was located on this deposit.

> "The solfatara situated in the drainage of the Anas River on the western slope of Mount Guianasan is still more energetic and important than the one in the Mapula ravine, but on the other hand possesses a much more ferruginous character than the others."

The extinct solfataras which Abella saw are situated at Guiso del Monte Panámao near Almeria and at Calmon near Naval. At the first he found clays, oxide of iron, and pyrite, the soluble substances and sulphur having disappeared. The second, which is near the sea and away from any stream, has a circular crater-like depression 50 meters in diameter and contains some clay deposits, but no sulphur.

Goodman, who visited the Island of Bilirán to examine the sulphur deposits, gives a description of them similar to that of Abella. He also noted a conglomerate on the beach about a half mile north of Almena, the boulders of which are encrusted with deposit of aluminous sulphate, probably alunogen, but of no commercial importance. In addition he refers to a hot spring near Catmon with a temperature of 107 F. and containing a small amount of gas, but no sulphur.

✓*Springs:* Besides the springs already mentioned as associated with the solfataras on Bilirán Island and near Burauen in Leyte and those related to the extinct volcanoes, Mount Amandiuing and Mount Cabalian, there is a small hot spring on the west side of the point of land which projects from Leyte opposite Poro Island in the Biliran strait and a hot sulphur spring on Mount Ogris south of Mount Nipga between Abuyog and Baybay. South of Abuyog in the barrio Buenavista there is a cold mineral spring. To the west of Alangalang, on the west side of the Cabayong River, there are some small and apparently nearly buried hills which are probably outliers of the Cordillera and at the base of one of these there is a cold mineral spring.

*Igneous rocks.*[a]—The rocks from the Cordillera which were collected by Jagor, were studied by Roth who states that there is an amphibolitic andesite at the gateway of the mountain of Dagami. Evidently he refers to the gateway in the mountain Himalicagan which Jagor passed on his way to the solfataras south of Burauen, since on Coello's map the names Dagami and Burauen are transposed. Roth, in his comments, states that the rock is exacty like that of Isarog, a dormant volcano in Camarines Sur, and that to the north of it there is a lapilli formation. This would seem to be a proof that there was once an active volcano near by and would support Jagor's statement that the solfataras are in a crater. In another portion of his article Roth writes that it is well known that Mount Dagami (Himalicagan) is an extinct volcano. Goodman found andesites at a locality near the solfatara.

According to Becker's opinion Abella's descriptions of the rocks of Biliran Island make it substantially certain that they are hornblende andesites.

The rocks which the streams bring down to the vicinities of Alangalang, Dagami, and Cabalian and which were collected during the reconnaissance on which this report is based, were mostly hornblende andesites with a few basaltic boulders.

One of Roth's conclusions is as follows:

> "Among the numerous volcanic rocks which I have from the south of Luzon, Samar, and Leyte and in the related tuffs, there are represented with few exceptions only two types, closely related, both being characterized by the presence of triclinic feldspars and distinguished one by hornblende, and the other by augite; hornblende andesites and augitic andesites or dolerites."

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[a] In this paper Kemp's classification of igneous rocks is followed. The petrographic determinations are by Dr. W. D. Smith.

*Sedimentary rocks.*—Thus far no sedimentary rocks have been reported as occurring in the cordillera in Leyte, and Abella did not mention any in his description of Biliran Island. However, according to a seemingly reliable report, there is an occurrence of petroleum on the east coast of Biliran, inland from the *sitio* Capalis, and it is quite probable that it is in sedimentary rocks.

The eastern flank of the cordillera is buried for a long distance by the alluvial deposits of the northwestern plains. The western flank from Ormoc to Baybay descends to the coast. The places where the relations of the sedimentaries may best be studied have not been visited, although it is certain from a few observations made during this reconnaissance that on the western flank of the Cordillera there is an extensive series of stratified deposits in which limestones are conspicuous. They are more fully discussed in describing the southwestern district. On the east side of the island similar limestones were seen at only one locality. At Patyucan point and extending inland to the road between Hinunangan and Hinundayan, there is a mountain called Patyucan which consists of massive and thinner bedded limestones which outcrop in conspicuous sea cliffs. They dip towards the south as if they had been given their inclination through a subsidence peripheral to the volcanic center, Mount Cabalían.

*Origin of the Cordillera.*—The trend of the Cordillera, as shown on the accompanying sketch map, is about N. 30° W. Abella has expressed his opinion that Biliran Island is due to a volcanic action and that it is a part of a volcanic belt which continues to the southward through Leyte and Panaón and the Eastern Cordillera of Surigao (Mindanao) to point San Agustín with some similar volcanic manifestations, and to the northward in the island of Maripipi and others until it connects with the active volcano Bulusan in Luzon, being thus situated on one of the volcanic fractures of the Archipelago. Becker cites this opinion of Abella and also the rather untenable theory of volcanic belts by Koto in his "Geological Structure of the Malay Archipelago" in which is included a structural line from Masbate through Leyte and eastern Mindanao. Especially suggestive are the following remarks by Becker,

> "To my thinking too much effort has been made to show unbroken continuity of volcanic zones. Fissures occur far more often in parallel systems than singly and, just as dikes jump from one fissure of such a system to another, so, I think, do the greater volcanic phenomena."

Much more study will be necessary before the relations of the volcanic zone of Leyte are determined definitely and in the meantime it will be better not to try to extend it too far. In the accompanying map Panaón Island is not included in the trend of the Cordillera, since it is not known to contain any true volcanic phenomena and the rocks seen in the northern end indicate that it is more closely related to the southwestern semi-mountainous district.

### SOUTHWESTERN SEMIMOUNTAINOUS DISTRICT.

If the limits of this district, as shown on the accompanying sketch map, are studied, it will be noted that between Ormoc and Baybay the Central Cordillera descends to the coast. Accordingly, the southwestern district is discontinuous and may be spoken of as consisting of a northern and a southern part.

The northern part contains a number of hills and low mountains which are indicated on d'Almonte's map, although no elevations are shown. They are situated in the western part of the area. The landscape in general presents a broken appearance, and near San Isidro and Villaba is a cogon hill country which formerly contained many haciendas devoted to the cultivation of sugar. Communication is largely by sea. There is, however, a trail leading north from Ormoc to Valencia and thence continuing northward to the head of the estuary into which the Leyte and Palapay Rivers flow. This trail passes through relatively low country and has a branch which turns to the eastward and crosses the Cordillera to Capoocan and Caragara. There are also branches from this trail which turn off at various points to Villaba and Polompon. The only improved road is one newly built from Ormoc to Dolores, which it will be impracticable to extend eastward over the cordillera to Jaro. The country along the trail north from Ormoc will probably develop into an important agricultural district, inasmuch as it contains a large amount of valley land. At present it is very sparsely inhabited.

The southern part of the southwestern district is more mountainous than the northern. To the south of Baybay there is a high ridge which runs in a southeasterly direction to a point opposite Bato, where there is a break in the mountains which is taken advantage of for a trail across this peninsular part of Leyte, the remaining roads of this area being along the coast. To the south of this route of travel there are mountainous ridges, one of which lies to the north of Maasin and the other to the west of Malitabog. Pananon Island, which is separated from Leyte by a narrow strait, appears to be a continuation of the mountains which parallel the coast south from Sogod. If we analyze the coast line of Leyte and judge of the trend of the mountains as shown by the position of the names on d'Almonte's map, we might be led to the same conclusion which was expressed by Becker, who, in his remarks concerning the structural lines of the Philippine Islands writes:

> "Near the center of our own Island of Leyte there is a fork in the mountain system, and the westerly branch is seemingly continued southward through Mount Apo and the southernmost part of Mindanao by the way of Sanguir Island to Celebes."

It is probable that this remark was based upon a study of the map of Leyte rather than its topographic features seen in the field. The coast line of d'Almonte's map is far from perfect. When the bay in the southern part of the island, which may have suggested the forking in the mountain systems, is properly mapped and the trend of the adjacent mountains is shown, it will be seen that the structure of the southwestern district is approximately parallel with that of the central cordillera.

*Sedimentary formations.*—At all of the places where the rocks of this district were examined, and in all of the landscapes which were studied while passing along the coast, conspicuous outcrops of coralline limestone were seen exposed on the flanks of the hills and even resting on the tops of some of the higher mountains. The relation of these outcrops to the topography and the apparent dip of the formations, as well as their attitudes when studied at close range, show that they have been elevated, faulted, and tilted. In some places masses were caught in between eruptive igneous rocks. It is probable that they were deposited on a basement of older igneous rocks and that with the gradual elevation and emergence of the Island of Leyte igneous rocks were intruded along some lines of fracture, giving rise to the dominant mountain trends. The sedimentary formations include beds of shales and conglomerates, but these are far less conspicuous than the limestones. In the northern part, near Eulalia, which is now known as Port Calubian, outcrops of coal are reported. Becker states that Leyte possesses coal but the locality is unknown, although it is said to be in the southwestern part of the island. It may be that the locality near Calubian is the one which furnished the samples which, as noted by Becker, were analyzed by the Inspección de Minas and shown to be of the same class as the Cebu coal, having a fuel value of 5,800 calories. On d'Almonte's map, the occurrence of petroleum is indicated at a point about 7 kilometers north of Villaba. It is reported that some prospectors have studied this part of Leyte and have found much to encourage them in the belief that petroleum exists there in paying quantities, but they have been deterred from developing the field because of the difficulty of enlisting capital.

*Igneous rocks.*—The igneous rocks of the southwestern district have been very little studied. From the island of Limasaua a specimen of hornblende andesite was determined by Oebbeke. During this reconnaissance some specimens of igneous rocks were collected to the west of Malitbog. They have been classified as diorites and peridotite porphyries.

The field relations of the igneous rocks to the west of Malitbog and on the northern end of Panaón Island, near Liloan, show clearly that eruptive and intrusive rocks have broken through the sedimentaries and included masses of the limestone. On the eastern side of Panaón, near Pinutan Point, d'Almonte indicates the occurrence of gold mines. Becker states that the wall rock at these mines was called by Ashburner "greenstone porphyry," and that this term, while it would not exclude prophylitic neo-volcanics, in all probability points to diorite or diabase.

*Gold Mines on Panaón Island.*—These mines were examined by Ashburner in 1883. From a manuscript report in the possession of Ashburner's clients, we have the following information given by Becker:

> "Several veins of quartz outcrop on the coast and extend in a westerly direction into the mountain. These veins are parallel. They strike east and dip south. The wall rock is 'green-stone porphyry.' There is some wall rock in the vein and the sulphurettes are generally pyrites and accompanied by galena and zinc blende. One vein about six feet wide has been worked to a considerable extent, some 871 tons having been treated up to 1883. The yield was $6 or $7 per ton. Concessions for gold mining have been granted at Tigbuan, just south of Pinutan, and, according to the Compendio de Geografia, there was a productive mine at Inalinan."

Becker further says that Ashburner found nothing which he could recommend to his clients. However, a mine which at that time was not attractive to capitalists, may prove worthy of exploitation when the conditions of the country are favorable to mining.

### NORTHEASTERN SEMIMOUNTAINOUS DISTRICT.

There is an elongate mountainous area to the west of the straits which separate Leyte and Samar Islands, in which the highest elevations are toward the northern end. There are some broken ridges on the east and west of the mountains, and to the south are isolated hills forming a continuation of the district. The rugged portion is heavily timbered and but sparsely inhabited.

From Tacloban, the principal port of Leyte, the road to the interior makes a detour of this district, first running to the south along the coast to the town of Palo, where it branches to the northeastern plains. South of Palo there are a few scattered hills situated near the coast and having their flanks partly buried by the sediments which constitute the plain.

*Geologic formation.*—The only note concerning the rocks of this district is by Jagor, who reported that he found a cliff of grayish green quartzose chloritic schists on the sandy beach about a league from Tanauan. This locality is evidently to the south of Tanauan about half way to Tolosa where there is such an exposure. Inland, in a long hill which the road touches in two places, this schist is more fully represented and is cut by dikes and larger intrusions of an augite andesite porphyry which probably produced the schist by metamorphosing the sedimentaries with which it came in contact.

Further south on the seashore, just to the northeast of Tolosa, there is a high subconical hill surmounted by an old tower built as an outlook and defense against the Moros. An exposure of rock in a sea cliff of a neighboring lower hill to the northeast shows an altered shale much squeezed and slickensided. Between Tolosa and Dulag there is a hill in which exposures near the road show a fine igneous rock which on microscopic examination proved to be felsitic andesite.

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About 1 kilometer to the west of Tanauan the United States Army opened a quarry in an isolated hill, in order to obtain stone for repairing the road from Tanauan to Dagmi. There is exposed in this quarry a squeezed, slickensided and very much altered rock which under the microscope showed only serpentine.

In the falls of the Milarong River to the west of Palo, and also in the hill near by, there is exposed an augite andesite with gabbroic texture. It is similar to the rock which is found cutting the schist south of Tanauan. The road nearer Palo cuts into a hill of altered shales. At Palo, at the north end of the bridge, a quarry has been opened for road material in a high hill of hard and slickensided and somewhat altered shale. The abutments of the bridge rest on exposures of this rock which produces a small fall in the river. The main area of the northeastern district was not visited, but such gravels as were seen from its streams indicate that the rocks which constitute it are similar to those found in the hills which form its southern continuation. The geologic history of the district, as may be interpretated from the data now available, indicates that the mountainous structure was due to the intrusion of igneous rocks into a series of sediments producing an uplift along an axis trending approximately north 30° west.

A peninsular part of Samar and the very irregular shaped Daram Island, as well as other lesser islands, lie to the northward, in strike with the northeastern district of Leyte, a fact which indicates that the structure continues to the northward. In traveling by steamer from Catbalogan, Samar, to Carigara, Leyte, and returning from Tacloban through the straits and interisland passages to Catbalogan, an opportunity was given to see the islands at close range, but no landing was made. The islands consist of sedimentary rocks with some igneous rocks which appear to form the axis of the trend, and, if they are not a continuation of the igneous rocks of northeastern Leyte, they at least follow parallel structural lines. Without landing and making a close examination it can not be determined whether they are intrusive or not, but the sedimentary beds do not appear to be altered and probably represent a younger formation than those which are cut and metamorphosed by the intrusives of the northeastern district of Leyte. In fact, at Tacloban, in the point of the peninsula on which the town is built, there are some low hills around which the Army post is located and exposures made by cutting roads show that the formation of which these hills are composed is a series of variable sandstones, shales and conglomerates, dipping at a low angle to the eastward. In the conglomerates there are pebbles and small boulders of igneous rocks which apparently had their origin in the northeastern district. Especially significant are the pebbles of schist. The hills in Tacloban were once islands, and they have been united to the mainland by a recent formation consisting of marine deposits and coral reefs which form the neck of the peninsula. A second peninsula of apparently similar origin but without any hills, lies to the east of the town, forming the limits of Cancabato cove. To the west of Tacloban the first low ridge consists of a series of sedimentaries very little exposed, but giving evidence of containing sandstones and some limestones. The direction of this ridge is about north 30° west. Looking across the straits to the north of Tacloban on the Island of Samar, there is a conspicuous hill showing a high escarpment, well toward its upper portion. This escarpment is due to the weathering of a thick bed of variable sandstone and conglomerate. In passing through the straits between Samar and Leyte, in the portion which has approximately a north south direction, one may observe outcrops of sedimentary beds dipping at low angles to the eastward. These are imperfect sandstones and nodular and concretionary argillaceous beds. The many changes in the direction of the channel in this part are due to the development of the channel by erosion along the strike of the least resistant beds which have an eastward dip and a strike of about north 30° west. The topography of the shores and the islands in the straits shows a series of hills or ridges and the channel occupies the lowest valleys between them, passing in a zigzag direction.

This series of sedimentary beds may best be studied on the Island of Samar where it contains some heavy limestones. Besides a number of sea cliffs which were seen in the small islands along its western shore, exposures were studied at Catbalogan and Calbayog. The formation is probably very extensive in Samar where its history may some day be worked out in detail. It is but slightly represented in the northeastern part of Leyte, and there is little certainty of correlating it with the sedimentary formation in the southwestern districts of the island because of the wide belts of the northeastern plains and the Central Cordillera which intervene. Nevertheless, the idea suggests itself that the sedimentaries of western Samar and southeastern Leyte belong to the same series which at present are not classified closely as to age, but which are now called late Tertiary.

## NORTHEASTERN PLAINS.

This district is the part of Leyte best adapted to agriculture because of the character of its soil and the general level surface of the land. It lies between the northeastern semimountainous district and the Central Cordillera, having considerable seacoast on Carigara Bay, and a longer coast line on the Pacific Ocean between Palo and Abuyog. Roads are being built to connect Carigara and Tacloban by the way of Palo, and to extend from Palo through Tanauan and Dagami to Burauen; and gradually this system will extend along the coast as far south as Abuyog, and have branches to all the important centers of population. Carigara is a very shallow port and ships must anchor well out in the bay. At low tide a broad beach is left bare, and the channel across it is too shallow for transporting cargo by lighters. On the east coast the towns are unprotected ports and open toward the Pacific. As a result, Tacloban, which has deep water and is well protected, will always receive a large amount of traffic from the plains district.

*Geologic formation.*—With the exception of a few exposures in low river banks which reveal very soft sandstones and poorly cemented conglomerates, little idea of the underlying formation of the northeastern plains can be obtained. Its surface deposits are largely alluvial and have been brought down by the streams from the Cordillera. Accordingly, near the foot of the Cordillera, coarser sediments are to be expected, and along the sea coast where the plains are low, little else is seen besides beach sand and silts deposited near river mouths. Reference has already been made to the partially buried hills, which are the southern continuation of the northeastern semi-mountainous district. The occurrence of some low hills near Alangalang which are probably outliers of the Cordillera district, has been noted in connection with the description of the Cordillera. Also reference has been made to the hills which surround Lake Bito. These are all inliers in the plain and give very little information as to the general formation. The only place thus far at which a deep well has been drilled in this district is Carigara, where artesian water was encountered at a depth of 56 meters. An examination of the samples of drillings which came from the well showed sands, detrital material from andesite rocks such as might have been brought in by rivers from the Cordillera, and interbedded marine sands containing marine shells. While it is not possible from the present data to prove the emergence of this plains district, it appears very reasonable to suppose that it was a strait at some period not very far removed, and that the elevation of the island has converted it into an alluvial plain, the surface of which has been aggraded by the streams. Marine sediments may be expected under the alluvial surface deposits.

## GEOLOGIC HISTORY.

Our present knowledge of the geology of Leyte is very incomplete but it points to an interesting history of the island which may be tentatively outlined as follows:

The basal formations do not appear in any area thus far studied unless the dioritic rocks represent the igneous portion of the older formations. Thus far diorites have been found only near Malitbog, and, possibly, as Becker has suggested, they are represented at the gold mines on Panaón Island.

In the northeastern district there is a series of sedimentaries, perhaps older Tertiary, which have been metamorphosed into schists and altered shales by intrusive igneous rocks. Some stream gravels indicate that a similar series of more or less metamorphosed sedimentaries and accompanying intrusives are present in the southwestern district. The erosion of these formations has contributed sediments to the later Tertiary.

The most widely distributed formation is a series which contains besides conspicuous beds of limestone, some shales, sandstones, and conglomerates. It is the predominating formation in the southwestern district and is reported to contain coal near Port Calubian (Eulalia) and petroleum north of Villaba. There is a small area of limestone of this series in the hills at Patyacan point on the east side of the Cordillera in the southeastern part of the island, and it is represented in the northeastern part of the island near the strait of San Juanico, and extensively in southwestern Samar. These sedimentaries are usually considered as later Tertiary. They have been lifted, faulted, and intruded by igneous rocks which appear to be closely related to the igneous rocks of the Cordillera.

The Central Cordillera of Leyte is a volcanic belt which extends in a direction north 30° west, through the island and continues in Biliran and Maripipi Islands. It contains the extinct volcano Cabalian, the solfataras south of Burauen, Mount Amandiuing, which is probably an extinct volcano, and the solftaras in Biliran Island. The rocks of this district are largely hornblendic andesites.

The northeastern plains, which are largely alluvial, represent the latest extensive formation. In addition there are some marginal littoral deposits formed in part of coralline limestone.

The emergences and submergences of Leyte and the adjacent islands, including especially Samar, form a complicated history. The coal in Leyte (and it may be noted that coal is also reported in western Samar but not yet known to be of economic importance) and the wide distribution of coralline limestone, in what is called the later Tertiary series of sedimentaries, indicates an extensive area of low-lying lands, coral reefs and shallow seas in late Tertiary time. The emergence of this series, which formed the Island of Leyte, seems to have been brought about by the igneous intrusions and volcanic eruptions which took place in the zone of the Cordillera. During the first stages of this process a strait probably extended in what is now the northeastern plains district. By continued elevation and the contribution of sediments from the Cordillera this strait has been transformed into an aggraded alluvial area. The development of the San Juanico Strait apparently occurred later and may be attributed to a submergence along an axis parallel to the Cordillera of Leyte, and perhaps resulting concomitantly with the growth in elevation of the central portions of the Islands of Samar and Leyte.

### SUMMARY OF MINERAL RESOURCES.

*Gold.*—The mines in Panaón Island have been abandoned for several years. If the veins permit of favorable mining and a yield of from $6 or $7 per ton can be obtained, as reported by Ashburner, it may be worth while to reopen the mines.

*Coal.*—The commercial value of the coal near Calubian probably depends more upon the character of the beds and facilities for delivering it at the sea coast, than upon the quality, since most Philippine coals are of about the same grade. Concerning the nature and location of the coal there are at present only hearsay reports.

*Sulphur.*—Goodman, from an examination of the surface estimated that there are about 3,000 tons of sulphur in sight at the To-od and Pangujan solfataras south of Burauen. At the mining claim San Antonio on Biliran Island there are 400 tons and at the Santa Rosalia claim the amount is inappreciable. He suggests the deduction of 25 per cent for loss in mining and treating. The cost of transportation from the Burauen deposits he considered prohibitive and the Biliran deposits too small to warrant the cost of installing machinery. However, transportation from Burauen to Tacloban will soon be improved by the completion of a good road, and since the remaining distance is short it may be that the sulphur can be exploited at a profit.

*Petroleum.*—No wells have been drilled and no study of the geologic structure near the oil showings has been made. There is some talk of prospecting at the showings near Villaba and on Biliran, but at present there is lack of capital for such an enterprise because of the attendant risk.

*Stone.*—Thus far two quarries have been opened for road material, one just west of Tanauan and the other at Palo. No doubt others will be developed in order to obtain stone of good quality for road building. Up to the present time gravel has been extensively used, but with better equipment crushed stone will be employed for road surfacing and a diligent search will probably reveal that it can be made available at many places.

*Clay.*—At present, ordinary pottery is manufactured at Tanauan and probably at some other towns which were not visited.

Formerly brick kilns were operated for burning soft brick at Baybay, but after supplying the local demand they were allowed to fall into disuse.

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## ILLUSTRATIONS.

PLATE I. Reconnaissance map of the geologic districts of Leyte. 357